ARI Research Note 89-03

Human Factors and Safety Assessment of Army Systems

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January 1989

United States Army
Research Institute for the Behavioral and Social Sciences

U.S. ARMY RESEARCH INSTITUTE FOR THE BEHAVIORAL AND SOCIAL SCIENCES

A Field Operating Agency Under the Jurisdiction of the Deputy Chief of Staff for Personnel

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REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1a. REPORT SECURITY CLASSIFICATION Unclassified	1b. RESTRICTIVE MARKINGS --
2a. SECURITY CLASSIFICATION AUTHORITY --	3. DISTRIBUTION/AVAILABILITY OF REPORT Approved for public release; distribution unlimited.
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE --	
4. PERFORMING ORGANIZATION REPORT NUMBER(S) --	5. MONITORING ORGANIZATION REPORT NUMBER(S) ARI Research Note 89-03
6a. NAME OF PERFORMING ORGANIZATION Essex Corporation	6b. OFFICE SYMBOL (If applicable) --
6c. ADDRESS (City, State, and ZIP Code) 333 North Fairfax Street Alexandria, VA 22314	7a. NAME OF MONITORING ORGANIZATION Army Research Institute Fort Hood Field Unit
	7b. ADDRESS (City, State, and ZIP Code) ARI Field Unit - Fort Hood HQ, TEXCOM (Prov) (PERI-SH) Fort Hood, TX 76544-5065
8a. NAME OF FUNDING/SPONSORING ORGANIZATION U.S. Army Research Institute for the Behavioral and Social Sciences	8b. OFFICE SYMBOL (If applicable) PERI
	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER MDA 903-86-C-0341
8c. ADDRESS (City, State, and ZIP Code) 5001 Eisenhower Avenue Alexandria, VA 22333-5600	10. SOURCE OF FUNDING NUMBERS

PROGRAM ELEMENT NO.	PROJECT NO.	TASK NO.	WORK UNIT ACCESSION NO.
6.37.39	A793	1.5.1	1.5.1.C.2

11. TITLE (Include Security Classification)
Human Factors and Safety Assessment of Army Systems

12. PERSONAL AUTHOR(S)
Avery, Larry W.

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Year, Month, Day)	15. PAGE COUNT
Final	FROM 86-10 TO 87-9	1989, January	34

16. SUPPLEMENTARY NOTATION
Charles O. Nystrom, Contracting Officer's Representative

17. COSATI CODES		
FIELD	GROUP	SUB-GROUP

18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
~~Human factors~~ Personnel, Health hazards, Continuous comprehensive evaluation, ~~MANPRINT~~ Training, ~~MPT~~ Logistics support, Manpower, Safety, ~~C2E~~ (cont'd.)

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

This report summarizes the human factors and safety assessment support provided to the U.S. Army Operational Test and Evaluation Agency (OTEA) during the planning and conduct of Follow-On Test and Evaluations (FOTE) of the M1A1 tank and the AN/TRC-170 Troposcatter Radio, the planning phase of the Mobile Subscriber Equipment (MSE) test, and the data collection phase of the SINCGARS V test.

The findings of this report provide "lessons learned" for addressing MANPRINT issues during the operational testing of hardware systems. These "lessons learned" indicate ways MANPRINT can be better integrated into test planning and execution.

Human factors and safety-related deficiencies that prevent fully satisfactory system performance are identified for the M1A1 tank and the AN/TRC-170 Radio.

Keywords:

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT	21. ABSTRACT SECURITY CLASSIFICATION
☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT. ☐ DTIC USERS	Unclassified

22a. NAME OF RESPONSIBLE INDIVIDUAL	22b. TELEPHONE (Include Area Code)	22c. OFFICE SYMBOL
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ARI Research Note 89-03

18. SUBJECT TERMS (Continued)

MSE
Mobile subscriber equipment
M1A1
SINCGARS-V
AN/TRC-170

HUMAN FACTORS AND SAFETY ASSESSMENT OF ARMY SYSTEMS

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HUMAN FACTORS AND SAFETY ASSESSMENT OF ARMY SYSTEMS

INTRODUCTION

General

This is a summary final report that documents the events over the term of Contract No. MDA903-86-C-0341. The report does not attempt to provide a detailed account of contractor performance of each task, but only to summarize them. More detailed information regarding the AN/TRC-170 test is contained in FH WP 8803, regarding the Multiple Subscriber Equipment in FH WP 8801, and regarding the M1A1 FOE in a Research Note that has not completed the publication steps. The SINCGARS publication awaits the completion of the test, the OTEA report, and the ARI report.

Background

At certain milestones during the acquisition cycle of U.S. Army materiel, test and evaluation (T&E) is performed to ensure that the design specifications are met and the materiel provides the required operational utility. This T&E is usually comprised of two types, developmental test and evaluation (DT&E) and operational test and evaluation (OT&E). DT&E is the responsibility of the Army Material Command (AMC), specifically the U.S. Army Test and Evaluation Command (USATECOM), and OT&E is the responsibility of the U.S. Army Operational Test and Evaluation Agency (USAOTEA) and the various test boards such as the Communications Electronics Board and the Artillery Board.

USAOTEA's mission is to provide an independent assessment of the operational utility of systems defined as major acquisitions. Data for this assessment is collected by exercising the system using Army personnel who are representative of the expected user population in operationally realistic but controlled scenarios. The intent is to determine the adequacy of the system to support operations and complete its mission in a tactical environment. Typical test issues include

1. Mission performance,
2. Adequacy of the Table of Organization and Equipment,
3. Vulnerability,
4. Reliability, Availability, and Maintainability,
5. Logistics supportability,
6. Adequacy of training and technical manuals,
7. Human factors,
8. Safety.

In recent years, the last three issues have become much more critical and visible, due primarily to the increasing complexity of the Army tactical

systems. New systems being developed and fielded are incorporating state-of-the-art technology into their design, especially computer technology. This complexity has so increased the task demands placed on the operators and maintainers that operational effectiveness is being jeopardized. This, along with the limitations on quality and quantity of personnel in the manpower inventory, has created significant concerns within the Army. The appearance and implementation of the MANPRINT initiative and of the continuous and comprehensive evaluation (C2E) concept are responses to these concerns.

Army Regulation 602-2, "Manpower and Personnel Integration (MANPRINT) in Materiel Acquisition Process" was effective as of 18 May 1987. It establishes a requirement for a MANPRINT Management Plan. MANPRINT is an umbrella concept integrating manpower, personnel, training, human factors engineering, health hazards, and system safety. The intent of MANPRINT is to support and influence systems design and associated support requirements so that developmental, non-developmental, and product-improved systems can be operated and maintained cost effectively and safely, and consistently with manpower structures, personnel aptitudes, skills, and training resource constraints. Thus, appropriate implementation of MANPRINT would ensure that factors such as limitations in the quality and quantity of personnel available in the current and future Army personnel pool, and training requirements are considered and explicitly planned for in the system design and acquisition. The development of MANPRINT methodology, subsuming human factors and safety (as in this contract), is a current ARI research task.

AR 602-2 directs the CG of OTEA to:

- Collect and evaluate soldier performance data (time and accuracy) for all critical operations and maintenance tasks in major and designated acquisition program testing and evaluation for which OTEA is responsible. (See AR 70-10 and AR 71-3.)

- Include soldier performance data on critical operations and maintenance tasks in any calculations of system effectiveness and availability presented to ASARC reviews.

- Assess effectiveness of proposed training for critical operations and maintenance tasks.

- Verify that soldiers used in testing are representative of the user population as defined in the target audience description."

This initiative ties in directly with the concept of C2E. OTEA is the Army's lead organization for the development and dissemination of C2E. It involves the collection and collation of data from a variety of sources such as USATECOM, contractor, USAOTEA, and the Human Engineering Laboratory into a single, integrated data base that will be used to evaluate systems from the conceptual design phase through and beyond deployment. The intent of this concept is to develop a historical data base that can be used to evaluate systems and provide lessons learned information for those having responsibilities for the acquisition of future systems.

USAOTEA and ARI (e.g., the Fort Hood Field Unit) had an agreement dating from 1983 wherein the Field Unit provided in-house support for the collection of human factors and safety data during selected (limited) OTEA operational tests. This support was increased by the transfer of OTEA funds to ARI and ARI's procuring contractor support to the effort. The present contract employs OMA funds, that being required when testing is at the Follow-on stage. During the period of this contract, the MANPRINT and C2E emphases have become urgent, and there has been pressure to change (enhance) the test support to meet the methodological requirements of MANPRINT and C2E, hardly feasible with the existing contract funding. OTEA fund citing has ceased; OTEA will do its own contracting for support of future tests.

Objectives

The objectives of this contract were to provide USAOTEA with human factors applied to follow-on test methodology development, field data collection, data analysis, and report preparation. Initially, there were six follow-on evaluations that were to be supported; AN/AN/TRC-170 Troposcatter Radio Follow-On Test and Evaluation (FOTE), SINCGARS V Follow-On Test and Evaluation (FOTE), Mobile Subscriber Equipment (MSE) FOTE, Maneuver Control System (MCS) FOE, M1A1 Main Battle Tank FOE, and Single Subscriber Terminal (SST) FOE. Of these six tasks, the SST FOE was cancelled and the MCS FOE was shifted beyond the scope of the contract. This report summarizes the support provided for the other four tasks.

TEST SUPPORT SUMMARIES

AN/TRC-170 Troposcatter Radio FOTE

Background

There is a DoD requirement for a high-speed, secure, digital transmission system that can accommodate the volume of digital voice and data traffic that is anticipated in the tactical battlefield environment of the 1980s and 1990s. The AN/TRC-170 Troposcatter Radio has been developed to meet a portion of the requirement.

The AN/TRC-170 V2 and V3 sets will be major elements in the Army's communications system called TRI-TAC. They are designed to fill the requirement for long-haul trunking of communications between major communications nodes. Set V2 provides a maximum effective range of 150 miles using a 9 ft. diameter antenna. Set V3 provides a maximum effect range of 100 miles using a 6 ft. diameter, trailer mounted antenna system. Both sets provide 128 to 2048 Kilobits per second transmission rate capability in the 4.4 to 5.0 GHz frequency band. The V2 set is housed in one S-280 shelter and one low profile pallet. The V3 set is housed in one S-250 shelter and one M-116A trailer chassis.

During the months of September 1986 and January 1987, a Follow-On Test and Evaluation (FOTE) of the AN/TRC-170 was performed at Ft. Huachuca, AZ. To this point in system development, the US Air Force, as lead service in the procurement, had been responsible for developmental and operational testing. The FOTE represented the US Army's first total and independent assessment of the AN/TRC-170 in the Army tactical operating environment, with soldiers.

Objectives

The objectives of the MANPRINT assessment of the AN/TRC-170 were to identify any aspects of the system design that required refinements in terms of human factors, safety, health hazard, training, and manpower considerations. Personnel was not a TRADOC issue for this test.

Method

The player personnel for the test consisted of 35 operators and three maintainers. MANPRINT data was collected using the following four types of data collection methods.

- Structured interviews were administered to the operators, maintainers, test directorate, unit commanders, and data collectors.
- Noise levels over the 500 to 2000 hertz range were measured in the shelters during high power operations, using an sound level meter and octave band analyzer.

- Observational data was collected by experienced MANPRINT personnel.

- Performance times were measured for crew performance of emplacement and displacement tasks. These tasks were the most critical and frequently performed. Forty-two separate measures were collected. Performance was measured using the standard four man crews, and with three man crews. Performance data regarding three man crews was collected to see if there could be any manpower savings.

In addition, a MANPRINT scoring conference was held to assess the impact on performance for each MANPRINT finding, and to determine the priority for correction of each finding. This is a new term for what had been called the Data Analysis Group's meeting(s). DAGs were divided into those personnel concerned with the validity of the data collected pertaining to RAM, and those concerned with the validity of the data pertaining to Human Factors. This conference consisted of representatives of USAOTEA, the AN/TRC-170 Program Manager's Office, TRADOC, and the manufacturer.

Results

In general, the system performed well as a radio relay. Twenty-four system deficiencies were identified, with the most critical listed below. Detailed findings are contained in FH WP 8803, "MANPRINT Test Report of the Follow-on Test and Evaluation of the AN/TRC-170 (V)", by Sam Bowser and Larry Lyons, 4 Feb 88.

HF Radio. There is no capability for high frequency radio communication between the AN/TRC-170 and other tactical, logistic and maintenance units.

M720 Shelter Mobilizer. The shelter mobilizer (M720) lacks high enough ground clearance for effective cross-country travel and the load capacity of its cargo, leading to equipment damage. Also, the mobilizer cannot be moved in reverse due to the height of the hitch and the angle of the mobilizer tongue.

Generators. The two 10-kw generators provided with the TOE cannot provide continuous power during switchover, and cannot automatically adjust for load variations.

Noise. The noise levels were measured at 89 dB(a) in the shelters during high power operations with the doors closed. This exceeds the 85 dB(a) criteria from MIL-STD-1474, and requires that hearing protection be worn at all times and limits voice communication to occasional shouted communications within two feet, unsatisfactory for a communications system.

Tailgates. The truck tailgates do not have steps and handrails for safe ingress to and egress from the shelter.

Low profile pallet. The lifting of the low-profile pallet, containing the 9.5 foot antenna, requires more than three men. If the crew is composed of only three, there is a high chance of injury.

Pionjar. When the crew were using the Pionjar, which is a handheld drill similar to a jack hammer used for drilling holes and inserting stakes in the ground, the noise levels exceeded 110 dB(a). The ear plugs supplied for hearing protection were not adequate.

Training. No training was provided as part of the 26D6 MOS training for the AN/TRC-170 on the use of the Pionjar, which could lead to inappropriate use and injury.

Emplacement and displacement. The TRADOC criteria for system emplacement was 240 minutes for the V2 and 120 minutes for the V3. This was from the time the unit drove onto the site until they were in communication. The criterion for displacement was 120 minutes for the V2. There was no displacement criterion for the V3. As Table 1 illustrates, the crew mean performance times exceeded these criteria in all cases. This was primarily due to several very difficult tasks, including the antenna alignment.

Table 1

Mean Performance Times (minutes) for Emplacement and Displacement of the AN/TRC-170, V2 and V3

		Emplacement		Displacement	
Equipment	Crew Size	Criterion	Mean	Criterion	Mean
V2	3	240	494	120	147
	4		360		134
V3	3	120	225	None	N/A
	4			194	

A number of difficulties were experienced in the collection of the performance data. First, the data collection was all manual. Therefore, the performance times could only be sampled due to limited coverage by MANPRINT personnel. Second, data was only collected during Phase 3 of a three phase test (Phase 1 was the pilot and Phase 2 was record testing) due to resource constraints. The changes in crew behavior and learning curves could not be determined. This limited the usefulness of the performance data.

SINCGARS V FOTE

Background

The SINCGARS V is a single channel, jam resistant radio that has the capability for membership in up to six communications nets. Jam resistance is achieved mainly through microprocessor-controlled frequency hopping. It has the capability for transmitting both voice communications and digital data. Entry of frequency and other types of data is accomplished by the use of an alpha-numeric keypad and other controls.

SINCGARS V is being developed as a replacement for the current family of US Army radios. There are two basic versions of the system, one for deployment in rotary wing aircraft and a ground version that can be either backpacked or installed in a vehicle. The upcoming operational test is a FOTE of the ground version.

One of the key issues for this FOTE is training effectiveness. ARI personnel at Ft. Hood revised the original TRADOC training issue statement to more adequately address two key questions: how well the troops were able to perform their tasks before, at the mid-point, and after the FOTE, and how could the training time be reduced. Essex personnel were requested to assist in the development of a training effectiveness evaluation plan to be used by ARI during the FOTE that would collect data to answer these questions.

Objectives

The objective of this effort was to develop a realistic, task-based performance test for assessing the effectiveness of the SINCGARS V operator training. The test was to measure how well troops performed the essential tasks before, at the mid-point, and at the end of the FOTE, and to determine whether the training time could be reduced without effecting the quality of the training.

Method

Four basic steps were utilized to produce the test methodology.

First, Essex personnel held meetings with representatives from ARI Fort Hood and the TRADOC Signal school to define the specific requirements for the effort, essential operator tasks, and the expected training content.

Second, Essex personnel reviewed training manuals, training materials, POIs, and the literature on training effectiveness evaluation. From this evolved a list of specific essential tasks on which the operator would be trained and a list of potential methods for assessing the effectiveness of training. The methods were reviewed and one selected that was most appropriate for the SINCGARS V training assessment.

Third, a draft methodology was developed that included task checklists. This was submitted to ARI for review and comment.

Fourth, the draft methodology was revised based on comments from ARI and submitted as a final product.

Product description

The methodology developed for the training effectiveness evaluation for the SINCGARS V FOTE consisted of the following four step process:

One, Administration of a post-training test. The trainees would perform each step of each essential task required to operate the equipment. Performance times would be measured, along with an assessment of whether the task was performed correctly (e.g., step performed, step performed in correct sequence, etc.).

Two, Subjective rating of training effectiveness. Subjective rating of training effectiveness. The trainers and trainees would rate the training given for each essential task as effective or ineffective. Comments would be elicited on deficiencies.

Three, Subjective rating of sufficiency of training time. Trainers and trainees would rate the sufficiency of the amount of time devoted to describing and practicing the essential tasks as not enough, about right, or too much.

Four, Comparison of ratings. The subjective responses obtained above would be compared with observed task performances in the posttraining test. This would allow a determination of those tasks which were not adequately explained or practiced. To assess those tasks where too much time was devoted would require direct observation in the instructional setting.

The steps listed above would be performed three times; at the end of training, at the mid-point of the FOTE, and at the end of the FOTE. The essential tasks that were identified are listed in Table 2.

Table 2

SINCGARS V Essential Tasks

1. Prepare Radio for Use
2. Operate SINCGARS V in the single channel (SC) mode
3. Prepare the SINCGARS V radio for frequency-hopping (FH) mode operations
4. Communicate with SINCGARS V radio net in the frequency-hopping mode
5. Join a SINCGARS V net which is already operating
6. Transmit data using SINCGARS V radio equipment
7. Operate SINCGARS V radio with COMSEC (KY-57)
8. Scan RT preset channels-SC mode
9. Use SINCGARS V radio relay station operations (retransmission)
10. Retransmit FH control instruction data
11. Perform SINCGARS V operator maintenance tasks

MSE FOTE

Background

The Mobile Subscriber Equipment (MSE) Non-Developmental Item (NDI) acquisition is one of the more critical of the current Army programs. The intent of the program is to purchase from industry a system that is basically "off-the-shelf" and can replace the current inventory of Army tactical telephone systems. The MSE is an assemblage of S-250 and S-250 extended shelter-contained communications equipment and supporting power systems that can provide voice and data communications support for a notional five division corps deployed in an air-land battle scenario. The system consists of up to 42 node center switches (NCS) connected by line-of-sight (LOS). Additional equipment includes the large extension node (LEN) switches, small extension node (SEN) switches, radio access units (RAU), mobile subscriber radio terminals (MSRT), and division and corps level system control centers (SCC). A more detailed system description, provided by the contractor, is included in Appendix A of ARI WP FH 8801: Preliminary Efforts Directed Towards a MANPRINT Evaluation of the Mobile Subscriber Equipment (MSE), 4 Feb 88.

The MSE is intended to provide the user with a secure, automatic, mobile, and survivable system that will pass data, facsimile, and voice traffic. The MSE will interface directly with Echelons above Corps (EAC), Combat Net Radio (CNR), other service, NATO, and commercial communications systems. The system is currently being developed by GTE under a contract that calls for an Initial Fielding/Follow-On Operational Test and Evaluation (FOTE) to start in May 1988.

Objectives

The initial objective of this support was to provide the MANPRINT input for the Independent Evaluation Plan (IEP). Later, the support objectives were expanded to include tasks for the preparation of a MANPRINT comprehensive continuous evaluation (C2E) plan for the MSE, and the collection and analysis of data from three pre-FOTE events that represented opportunities for performing C2E. These three events were the following:

- The System Control Center (SCC) man-machine demonstration and hands-on exercise,
- The cosite interference test (CIT),
- The field installation verification (FIV) demonstration.

Method

The methods used for performing each of the subtasks in this task are briefly described below.

MANPRINT IEP Development. The IEP is one of the more critical of the documents associated with an operational test. It defines the issues, criteria, evaluation methodology, and data required to perform the evaluations and answer

the issues. The IEP becomes the template for all the other test documentation, such as the Test Design Plan (TDP) and the Detailed Test Plan (DTP).

The MANPRINT portions of the MSE IEP were developed in four steps. The first step involved a review of the current test documentation. This included USAOTEA Memorandum 10-3, the TRADOC issues and criteria, various contractor supplied system descriptions, and the existing portions of the MSE IEP.

The second step involved a refinement of the issues and criteria. The existing TRADOC criteria were clarified by the inclusion of a more detailed, precise description of the intent of the criteria in terms of human performance. They were also expanded to include USAOTEA supplied criteria, specifically in the domains of personnel and human performance measurement.

The third step was to define the techniques required to evaluate the issues and criteria, including the data required for evaluation, and develop a draft MANPRINT section for the IEP. This was submitted to ARI and USAOTEA for review and comment.

The final step was iterative and involved a succession of revisions of the MANPRINT section based on ARI and USAOTEA comment and on insights gained from Essex personnel during C2E activities. A final revision was submitted to ARI and USAOTEA in September 1987 for incorporation into the MSE IEP.

Development of the C2E Plan. As in any research effort, the first step in the development of the MSE MANPRINT C2E plan is to review the relevant documentation. This consisted of reviewing the IEP, various contractor test plans and schedules, the MSE System MANPRINT Management Plan (SMMP), USAOTEA Memorandum 10-3, and attending MSE conferences. It became evident during this effort that there was insufficient guidance available for the content and format of a C2E plan. The available documentation was reviewed to determine what events were upcoming in the production lead time activities, what data could possibly be obtained during each event, and what the current MANPRINT concerns were for the MSE.

From this review, a draft plan was developed that specified events, expected data, and a rough schedule for data collection. This plan was very general and designed to elicit more concrete input from ARI and USAOTEA. Based on their comments, a second, more detailed, draft plan was developed and submitted for ARI and OTEA approval.

C2E Data Collection. Three data collection efforts were undertaken for the C2E of the MSE. These involved evaluating demonstrations of different aspects of the system design by the contractor and the program manager's office (PMO). The demonstrations were the System Control Center (SCC) Man-Machine Demonstration and Hands-On Exercise, the Mobile Subscriber Radiotelephone Terminal (MSRT) Cosite Interference Test (CIT), and the MSRT Field Installation Verification (FIV).

The SCC Man-Machine Demonstration and Hands-On Exercise took place at the contractor site in Massachusetts, where the PMO was conducting a demonstration of the system using three representative operators. The SCC demonstration equipment consisted of SCC Command shelter equipment:

(2 each - Visual Display Units (VDUs) with keyboards,
(1 each - Graphics Display Unit (GDU) with operator's console,
(1 each - UGC-74B teletype with keyboard), Technical Shelter equipment
(2 each - UGC-74B teletypes,
(the duty teletype with keyboard,
(the logbook teletype without keyboard,
(all required processor bay equipment and peripherals needed for the demonstration,
(NCS simulator that was used to return acknowledgement and status reports during the scenario.

Data collection consisted of recording participant demographics, taking notes and collecting handout information during classroom instruction, making observations during the hands-on exercise, and recording interview comments during the debriefing interview. Data analysis consisted of a review, summarization, and categorization of all collected information, and the identification of potential problems associated with the anticipated SCC design.

The MSRT CIT was conducted at Ft. Huachuca, Arizona, by the PMO to determine whether the MSRT and typical CNRs interfered with each other when colocated. The basic design of the CIT consisted of the use of two jeeps equipped with a MSRT and a CNR, and two jeeps equipped only with a CNR. The jeeps acted as teams, each team was composed of an MSRT equipped jeep and a CNR only equipped jeep. One team was stationary and the other was mobile, placing calls at certain distances from the stationary team. The distance between the MSRT antenna and the colocated CNR antenna was varied as one of the independent variables.

The objectives of this C2E effort were to glean any data that might provide answers to existing MANPRINT issues and concerns, and obtain insights into potential human performance problems that need to be examined during the FOTE. The MANPRINT data collection was performed using two methods; observation by an experienced MANPRINT person, and a structured interview with the operators at the conclusion of the test. The observations were performed primarily during the pretest training and at intervals during the test, and were used to develop items for the structured interviews. Four operators were drawn from the expected target audience, but the structured interviews could be conducted with only two of them.

The MSRT FIV was conducted at Fort Hood, in conjunction with an antenna pattern test. The objective of Essex attendance at the FIV was to look for potential MANPRINT domain problems to be studied during the upcoming FOTE. Contractor personnel viewed the FIV solely as a means of verifying the adequacy of the installation instructions in their draft technical bulletins. The 31 Victor MOS personnel (three in a team) performed most of the actual work, but were closely observed and guided by contractor personnel. Once the installation was completed, contractor personnel checked the system to ensure that all

connections were properly made, and then removed the equipment. The antennas were left in place for the antenna pattern test which was conducted at another site. The Mobile Subscriber Radio Terminal (MSRT) was not employed in the antenna pattern test. Rather, a separate signal generator, not a part of the system itself, was used for this test.

The MSRT was not placed in operation during the FIV. Only one MSRT was available, so it would not have been possible to determine whether the system was functioning. One demonstration of initialization of the system with the stand-alone kit was conducted. The primary purpose of the demonstration was simply to verify the instructions to the operator. Because a number of persons were observing the demonstration, it was not possible to ask questions.

Results

The following paragraphs briefly describe the results of each of the MSE subtasks.

MANPRINT IEP Development. The MSE IEP described the issues and criteria for testing the system, and how the data would be analyzed to answer the issues. The MANPRINT portion of the MSE IEP contained four subissues and a number of attendant criteria. These are listed in Table 3, along with USAOTEA comments. For each of these subissues, the analysis methods emphasized the need for objective, human performance data as much as possible. Writing the IEP also provided the following insights into the requirements for developing the MANPRINT parts of an IEP.

- First, it became evident that some domains of MANPRINT are very difficult to test. This is particularly true for manpower. There needs to be research into methods for collection, analysis, and evaluation of data relative to the impact of a system on the manpower requirements of units and the Army as a whole. In many cases it may be necessary for this type of data collection to be performed after fielding, as part of a C2E effort. A field unit probably is not the appropriate place to respond to the total manpower issue.

- Second, a very important aspect of the preparation of the MANPRINT parts of an IEP is integrating MANPRINT with the remainder of the IEP sections. The MANPRINT data requirements should be embedded in all the other sections as necessary, especially the performance issues. MANPRINT, as an issue, cuts through all others and should not be treated as a totally separate element. The data for MANPRINT will usually be collected during the scenarios and trials done for the other issues, not in a stand alone manner. To ensure that MANPRINT is treated adequately, the human performance data collection must be embedded within all the relevant issues.

- Third, while there is a tremendous and justifiable interest in more objective human performance measurement in operational test, it is very difficult to collect this type of data currently. This is due to two factors. One, there are few techniques or methods currently available that are appropriate for Army operational tests. There needs to be more

research to develop methodology for human performance measurement in operational testing. Two, for the current and future methods to work, the test design must be better controlled and more oriented towards the measurement of human performance. Currently, the emphasis tends toward designing the test for RAM and hardware performance, with inadequate thought given towards how to maximize human performance data collection.

Development of the C2E Plan. The C2E plan, as delivered, provided a general management document for USAOTEA to pursue the MANPRINT C2E of the MSE. The acquisition cycle was divided into two phases, the Production Lead Time (PLT) and the Follow-On Test and Evaluation (FOTE). Table 4 illustrates potential data sources that were identified in the Plan, by phase. Figure 1 illustrates the MSE C2E process. Table 5 lists the initial MANPRINT issues. These issues were drawn from the System MANPRINT Management Plan (SMMP) and the IEP. Table 6 provides a matrix of data collection events by MANPRINT issue. It became apparent during the development of this plan, that it had not been started early enough in the development cycle (e.g., PLT) of the system. Many potential data collection events, including the three discussed on page 23, were occurring before the plan was completed. Obviously, a C2E plan must be developed at the very beginning of the acquisition cycle and revised as more is learned.

Table 3

MANPRINT Issues and Criteria From the MSE IEP

Support Issue 4. Manpower and Personnel Integration (MANPRINT) Elements.

Subissue 1: Does the training provide necessary knowledge and skills for users, operators, and maintenance personnel to employ and maintain the MSE System?

USAOTEA Comment: The major concern here is whether the pre-test training is sufficient to prepare the operators and maintainers for performing their required tasks in an operational field environment. Implicit in this issue is the determination of whether human performance problems either measured or observed during the field test can be attributed to inadequate training or design deficiencies in the MSE hardware and software.

Criteria:

Upon completion of the pretest training in the individual and collective training plan, 80 percent of the users, operators, and maintainers will be able to perform 90 percent of the critical tasks to the prescribed standard outlined in the training material.

At least 80 percent of the crews must complete 100% of the crew critical tasks.

USAOTEA Comment: In general, "critical tasks" are understood to be those which are essential to successful mission performance and are of high difficulty level (hence high error probability). Crew critical tasks are understood to be those performed collectively by personnel. These critical tasks have yet to be identified.

The training program and support material must provide sufficient information to plan, install, maintain, operate, and supervise the MSE System in the judgement of 80 percent of the key players and key test personnel.

Table 3 (cont.)

MANPRINT Issues and Criteria From the MSE IEP

Subissue 2: Are the MSE signal battalions properly organized to provide communications support for the command and control of support units?

USAOTEA Comment: The major concern here is whether there are adequate numbers of qualified personnel to allow for proper MSE Signal Battalion manning and organization. The issue could be restated as follows: Are the MSE Signal Battalions manned by sufficient numbers of troops having the prerequisite aptitudes and skill levels? This issue represents the MANPRINT domains of manpower and personnel.

Criteria:

No additional personnel are required for any MSE assemblage to meet mission requirements in the judgement of at least 80 percent of the key players and key test personnel.

No additional personnel are required to command, control, plan, install, operate, maintain, or manage the MSE network in the judgement of 80 percent of the key players and key test personnel.

No additional NRI equipment or personnel are required to provide interface from Combat Net Radio system (SINCGARS and AN/VRC-12 series radio) in the judgement of 80 percent of the key players and key test personnel.

USAOTEA COMMENT: NRI equipment is not normally a part of the MANPRINT assessment, but will be conducted by the MANPRINT personnel during the MSE FOTE.

Operation and maintenance of the MSE assemblages does not require skills and aptitudes greater than those typical of personnel representing the full range of characteristics of the designated MOS. The Military Occupational Skill (MOS) categories designated should permit the selection and classification of MSE operators and maintainers having the necessary aptitudes, skills, and qualities to 1) perform the required tasks, and 2) be trained to an acceptable level of performance on these tasks under all likely operational conditions.

Table 3 (cont.)

MANPRINT Issues and Criteria From the MSE IEP

Subissue 3: Do the human factor engineering (HFE) aspects of the MSE System assemblages provide for reliable and efficient operation and maintenance by representative soldiers?

Criteria:

Operators and maintainers will be provided with adequate workspace to perform their mission.

USAOTEA Comment: This will include functional layout of components of the system within the shelter, as well as all aspects of habitability such as lighting, noise, heating/air conditioning/ventilation, etc.

Adequate storage space for TMs, tools, parts, personal gear, individual weapons, and all other items necessary to perform the mission is provided.

Controls, displays, and other equipment will be operable by representative soldiers while wearing cold weather clothing (Zone 6 with arctic gloves in a non-shelterized environment) and/or Nuclear-Biological-Chemical MOPP IV protective clothing (for use in shelterized assemblages).

Components are easily accessible to maintenance technicians.

The MSE System will be designed to enable installation, operation, and transport IAW good human factors engineering principles.

The man-machine interface will be user friendly to allow the performance of the mission.

The capabilities of the MSE assemblages must be compatible with that required by the users to perform the necessary tasks and missions.

Human performance of the expected operational and maintenance tasks is not degraded by any aspect of the design of the human-system interface.

Table 3 (cont.)

MANPRINT Issues and Criteria From the MSE IEP

Subissue 4: Is the MSE System's equipment safe for representative soldiers to operate and maintain?

USAOTEA Comment: USAOTEA understands that all relevant health and safety issues are to be considered. These will include such problems as fire, radiation, explosions, cutting/blunt surfaces, environmental extremes, and electrical shock.

Criteria:

The MSE System equipment and assemblages will not pose any unacceptable safety or health hazard to the operator or the maintainer. "Unacceptable" is defined as a critical catastrophic safety or health hazard as defined by MIL-STD-882.

USAOTEA Comment: Critical hazards are those likely to cause severe illness or injury or major system damage. Catastrophic hazards are those likely to result in death or system loss.

Hazards that are an unavoidable part of the system configuration, operating conditions, etc., must have adequate safeguards to minimize the likelihood of injury to personnel.

Table 4

Potential Data Sources for MSE by C2E Phase

Data Source	PHASE OF SYSTEM LIFE CYCLE PLT	Initial Fielding
Previous Test Results (OT, Predecessor System's Software)	X	
Shelter Product Assurance Test (SPAT)	X	
Product Assurance Test and Evaluation (PATE)	X	
Product Reliability Assurance Test (PRAT)	X	
Technical Manuals	X	X
Safety Reports/Releases	X	X
Other Contractor Documents	X	
AMSAA IER		X
Human Factors Engineering Analysis (HFEA)		X
Health Hazards Assessment (HHA)	X	
Destination Final Acceptance Testing (DFAT)		X
Doctrine and Tactics Training		X
New Equipment Training (NET)		X
Field Training Exercise (FTX)		X
Follow-on Operational Test and Evaluation (FOTE)		X
USAOTEA IER		X

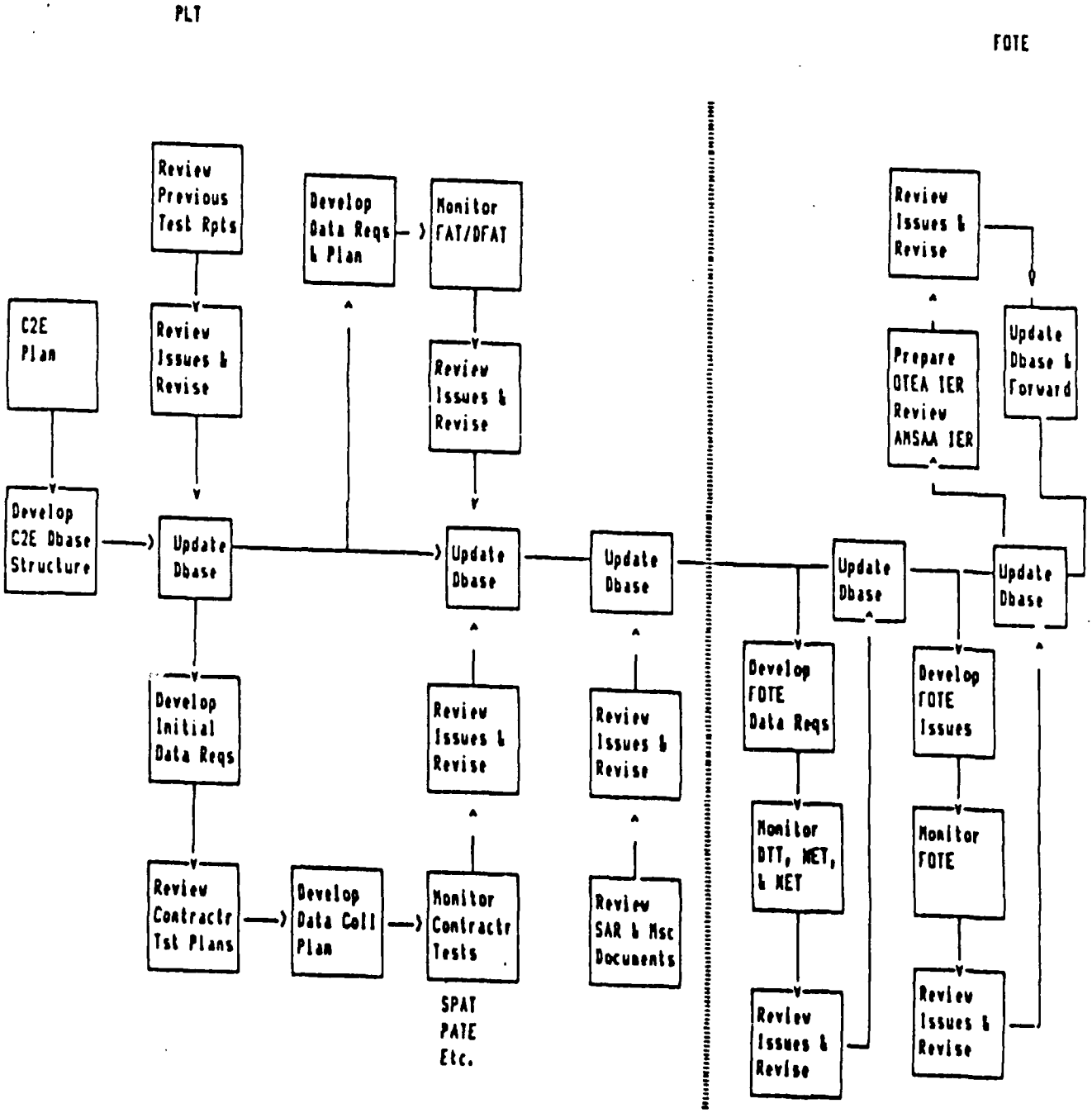

Figure 1. Functional flow of Major Activities for the MSE C2E Process

Table 5

MSE MANPRINT C2E Issues, By Domain

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1. Manpower.

a. Assemblage Personnel. Are additional personnel required for any MSE assemblage to meet mission requirements?

b. Network Personnel. Are additional personnel required to command, control, plan, install, operate, maintain, or manage the MSE network?

c. IDS Maintenance Personnel. Will there be sufficient numbers of IDS maintenance personnel for repair of the C-E equipment in the MSE Signal Battalion?

2. Personnel.

a. Adequacy of Skills. Does operation and maintenance of the MSE assemblages require skills and aptitudes greater than those typical of personnel representing the full range of characteristics of the designated MOS?

b. Feeder MOS Impact. What will be the impact of the feeder MOS' not being required to possess the objective aptitudes (Electronics, General Technical, Reading Grade Level) for transition to the MSE MOS?

c. Unit Level Maintenance. Will the operators be capable of executing unit level maintenance on assigned equipment?

3. Training

a. Transfer of Knowledge. Does the training provide necessary knowledge and skills for users, operators, and maintenance personnel to employ and maintain the MSE System?

b. Individual Performance. Upon completion of the pretest training in the individual and collective training plan, can 80 percent of the users, operators, and maintainers perform 90 percent of the critical tasks to the prescribed standard outlined in the training material?

c. Crew Performance. Can at least 80 percent of the crews complete 100% of the crew critical tasks after collective training?

d. Training Material Content. Do the training program and support material provide sufficient information to plan, install, maintain, operate, and supervise the MSE System?

Table 5 (cont.)

MSE MANPRINT C2E Issues, By Domain

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4. Human Factors Engineering

a. Workspace. Are Operators and maintainers provided with adequate workspace to perform their mission?

b. Storage Space. Are adequate storage space for TMs, tools, parts, personal gear, individual weapons, and all other items necessary to perform the mission provided?

c. MOPP IV, Cold Weather Operations. Are controls, displays, and other equipment operable by representative soldiers while wearing cold weather clothing (Zone 6 with arctic gloves in a non-shelterized environment) and/or Nuclear-Biological-Chemical MOPP IV protective clothing (for use in shelterized assemblages)?

d. Accessability. Are components easily accessible to maintenance technicians?

f. Compatibility. Are the capabilities of the MSE assemblages compatible with that required by the users to perform the necessary tasks and missions?

g. Design for Human Performance. Is human performance of the expected operational and maintenance tasks degraded by any aspect of the design of the human-system interface?

h. Tongue Weight. Will the tongue weight of the PU-753 (equal to 153 lbs) prohibit use of the 5th percentile female as MSE personnel?

5. System Safety and Health Hazards.

a. Safety and Hazards. Do the MSE System equipment and assemblages pose any unacceptable safety or health hazard to the operator or the maintainer? "Unacceptable" is defined as a critical catastrophic safety or health hazard as defined by MIL-STD-882.

b. Safeguards. Do hazards that are an unavoidable part of the system configuration, operating conditions, etc., have adequate safeguards to minimize the likelihood of injury to personnel?

Table 6

Anticipated MSE C2E Data Returns by Major Event and MANPRINT Issue

ISSUE	EVENT SPAT	PATE	PRAT	DFAT	DTT	NET	FTX	FOTE	FUTURE*
Manpower									
1a Assemblage Personnel				0			X	X	X
1b Network Personnel					0	0	X	X	X
1c IDS Maintenance Personnel					0	0	X	X	X
Personnel									
2a Adequacy of Skills				0	0	X	X	X	X
2b Feeder MOS Impact					0	X	X	X	X
2c Unit Level Maintenance						X	X	X	X
Training									
3a Transfer of Knowledge					X	X	X	X	X
3b Individual Performance						X	X	X	
3c Crew Performance						X	X	X	
3d Training Material Content					X	X	X	X	
HFE									
4a Workspace	0	X	0	X	X	X	X	X	
4b Storage Space	0	0		0		0	X	X	
4c MOPP IV, Cold Operations							0	X	
4d Accessibility			0			X	X	X	
4e Compatibility							X	X	X
4f Design for Human Performance							X	X	
4g Tongue Weight							X	X	
Safety/HH									
5a Safety		0		X		0	X	X	
5b Health Hazards		0		X		0	X	X	

Notes: * Future indicates that data to complete the assessment of this issue will come from events beyond the FOTE.

X means that data can be acquired, 0 means that only indications of potential issues can be acquired

C2E Data Collection

For each of the MSE C2E events monitored by Essex personnel, the data return was not as great as expected. This was primarily due to the MANPRINT personnel not being in the role of controller of data collection. The events were organized by the PMO and the objectives were to demonstrate aspects of the system design other than MANPRINT. In all cases, concerns regarding the design of the MSE were raised. These are briefly described below.

SCC Man-machine demonstration & hands-on exercise. Based on the SCC Man-Machine Demonstration and Hands-On Exercise, it appears that U. S. Army Signal Corps personnel can effectively use the SCC for network management in terms of opening, moving, and closing network elements and their associated links; however, the efficiency and accuracy of their performance may suffer from usability and readability of reports, messages, VDU screens, and the GDU graphics. The capability of the operators to perform these functions in the shelter-mounted equipment and in a battlefield environment cannot be assessed from the data collected. The capability of the operators to perform functions of the SCC other than the three mentioned above is also unknown.

A major concern, based on the results of this event, is the overall quality of the operator-machine interface. A number of items were identified that indicate that this interface is less than ideal at this point in its design cycle. The primary items of concern that were identified are as follows.

- Compatibility of labeling of the equipment, and the screen/report formats with American stereotypes and U. S. Army expectations appear to be questionable. The current displays are based on French and precursor system design, and labels have been translated from French.

- The quality of the GDU display appeared marginal in producing crisp, clear images with adequate brightness.

- Graphics coding on the GDU is very complex and must be fully reviewed by HFE and Signal Corps subject matter experts.

- Hardcopy reports were not available in the appropriate shelters where such reports function as an operator aid. Useful hard copy reports are not available for printout at all the shelters that could use them.

- Definition of functional tasks and their allocation to various crew stations, especially in terms of crew workload must be verified as reflecting the U. S. Army doctrine and operating philosophies for the network.

Cosite Interference test. The cosite interference test produced a low data return for MANPRINT. In general, the physical size of the terminal was larger than expected, taking up a large part of the back of the jeep. The control and display surface was cleanly designed, with little visual clutter. The test data from the CIT seemed to support the original hypothesis of an interference problem between the MSRT and the CNRs.

Based on the results of this MANPRINT data collection effort on the MSRT, there are a number of concerns that need to be further examined during the FOTE. Each is discussed below.

- First, it is obvious that the cosite interference problem has direct relevance to training and doctrine. The doctrine regarding the placement of CNRs relative to the MSRTs will need to be established and introduced into the training for the operators and users of the MSRTs. This issue needs to be followed up with data collection during all phases of the test, especially phase III when the unit is free playing.

- Second, it was observed that the operator had to input user identification and frequency data through the DSVT/DNVT handset without visual feedback of correct data entry. Without the benefit of a display for visual reference, many errors could be introduced by the operators. If the MSE system does not have a suitable error checking capability built-in, data on the frequency of errors and the impact of these errors on unit communication needs to collected during all phases of the FOTE.

- Third, during the training it was indicated that occasionally there would be a loss of dial tone. When this occurred, the operator was to tap the switchhook on the DSVT/DNVT or turn the system off. This loss of dial tone needs to be further explored from both a RAM standpoint and to determine if this leads to loss of incoming calls.

- Fourth, it was observed that the indicator lights washed out in bright sunlight and the audible alarm frequency is the same as the incoming call signal. While the operators reported little difficulty with this, given the limited nature of the exercise the indicator light brightness and the audible alarm frequency need to be explored more to determine if there could be any behavior impact on the operators.

Field installation verification. The FIV was an exploratory effort by the PMO to look at the installation concepts for the MSRT in various vehicles, the hardware required for installation, the installation procedures, and the manuals. The following potential MANPRINT issues were observed during the FIV and need to be explored more fully during the FOTE.

- The manuals were difficult to use due to steps being out of sequence, drawings not being in scale, lack of exploded drawings, and part numbers referenced in the manuals not matching the actual part numbers.

- There were a number of problems with the vehicle installations. In the M151 Jeep, the antenna mount was on the road side and in front of the driver. The antenna could not be adequately tied down without danger of it shorting out when it touched metal. In the M1008 CUCV, the DSVT was strapped to the front seat between the driver and the passenger. This precluded a third person riding in the cab. In the M113 Personnel Carrier, the MSRT mounting extended forward of the passenger back seat rest. This could lead to injury to personnel.

- Noise levels in tactical vehicles tend to be high. These levels could mask the sound on the incoming call alert.

- Vehicle mounting holes locations were determined by using a tape measure. Drilling templates would be much more accurate.

- There was no installation tool kit. Several times the installers were observed to borrow tools from personal tool kits, such as a right angle drill. A complete installation tool kit should be supplied with the equipment.

- Spares of parts such as bolts and nuts were not included in the installation kits. Installers were observed obtaining parts from hardware stores to replace lost or damages parts. The installation kits should include spares.

M1A1 Main Battle Tank FOE

Background

The M1 Main Battle Tank has been evolving over the last ten years. The latest design is designated the M1A1 Abrams and resembles its predecessor in most respects. The design changes consist primarily of the following:

- Substitution of a 120mm main gun for the 105mm main gun. The 120mm gun uses combustible-case ammunition, and requires a new weapon mount and redesigned fire control system.
- Improved armor protection.
- Improved suspension system, transmission and final drive.

Forty-one (41) M1A1 Abrams were being fielded for the first time to the 3rd Squadron, 3rd Armored Cavalry Regiment (ACR) at Ft. Bliss, Texas. USAOTEA performed a FOE of the M1A1 from January to June 1987, supported by ARI in the area of MANPRINT.

The FOE used an expanded sample data collection (SDC) methodology to evaluate M1A1 production models during new equipment training (NET) and unit ARTEPS. The primary test issues were as follows.

- Can the M1A1 tank main gun be calibrated using procedures prescribed in the "M1A1 Calibration Policy," FC-17-12-1A1, Tank Combat Tables?
- Have the materiel deficiencies disclosed during the M1E1 OT II been corrected?
- Can the M1A1 tanks be supported with planned logistics concepts?
- Can the M1A1 tank crews effectively use the on-board nuclear, biological, and chemical (NBC) system?

Objectives

The objectives of the MANPRINT assessment were to provide supporting data and information to address the test issues described above.

Method

The data collection methods used in the M1A1 FOE consisted of subjective techniques. It was originally intended for there to be some human performance data collection, but the noninterference requirement imposed on the FOE by the host unit would not allow any instrumentation of side tests. Therefore, data collection relied on structured interviews, questionnaires, task checklist completion, and debriefs.

The data were collected in three stages. During January and February, 1987, demographic data and training observations were collected during the NET. Post-ARTEP debriefs of the crews were conducted during April 1987, along with limited observations. At the end of the FOE, during June 1987, interviews were conducted with the test directorate, unit commanders, and data collectors. In addition, final questionnaires were administered to the crews.

Results

The MANPRINT efforts during the M1A1 FOE focused on the second test issue: were the MANPRINT deficiencies found during previous testing of the M1E1 during OT II corrected? Of the 29 deficiencies previously reported, 11 (38%) were not corrected in the M1A1. This included the following:

- No provision for human waste elimination and disposal during prolonged buttoned-up operations.
- Inadequate storage space for personal gear.
- The NBC system does not protect the crew from Carbon Monoxide (CO) gas, it only removes the odors (propellent fumes?) associated with the gas. This makes it all the more insidious a threat.
- The noise from the NBC system interferes with conversation over the intercom system.
- Driver's seat provides inadequate back support.

According to the questionnaire and interview data, the crews could calibrate the main gun rapidly and effectively. Supporting data from gunner accuracy was not available. The only major negative comment regarding the main gun system indicated that there was considerable drift, requiring correction every 15 minutes or so. The crew indicated that the drift was much worse than the M60's 105mm gun.

The major reported difficulty with the logistics concept was in the resupply capabilities. The crews indicated that the platoons needed about 50% more personnel and transportation resources to effectively resupply the M1A1 platoons during extended missions.

In addition to the lack of protection from CO mentioned above, a number of other problems were identified relating to the on-board NBC system. These included the following:

- The Units' Standard Operating Procedure (SOP) needs to be revised to accommodate the new NBC system.
- Training for the NBC system needs to be expanded to include how the system works and how to troubleshoot.

- The NBC system exhaust on the left side of the tank is very hot, and can cause burns to personnel or possible fires. This needs to be protected or vented better.

Additional findings from the MANPRINT evaluation of the M1A1 during the FOE include the following:

- The heater tends to fill with dust. The impact of this is unknown at present.

- The front fuel caps do not lock open while fueling. They become an inconvenience and can fall on a crew member's wrist and cause injury.

- New equipment training (NET) was rated good. It was felt that a specialized NET should be added for those personnel who were already 19K MOS. They were trained on topics that were consistent with their previous M1 experience. They felt that this was redundant and a NET for only those differences was a better approach.

- It was felt that the scout personnel should have some M1A1 training to make them familiar with the capabilities of the system, because they have to work closely with the M1A1 units.

DISCUSSION

Essex Corporation, through ARI Fort Hood, provided MANPRINT test and evaluation support to USAOTEA for four operational systems: AN/TRC-170, SINCGARS V, MSE, and the M1A1. This support included definition of data collection methodology, data collection, data reduction and analysis, and report preparation. In addition, Essex personnel worked towards defining methods for the development of MANPRINT and C2E plans, human performance measurement in operational testing, and field training assessment. The validity of some of these methods will be determined in future testing.

There were a number of issues regarding MANPRINT operational test and evaluation that introduced difficulties to the test teams and should be briefly discussed here.

The first issue involved is measuring human performance during Army operational testing, one of the goals of USAOTEA. Based on the experiences of MANPRINT personnel during this contract, there are a number of difficulties in meeting this goal. First, to reliably collect human performance data, the test design must lend itself to human performance measurement under experimentally controlled conditions. As experienced during the M1A1 FOE and the AN/TRC-170 FOTE, MANPRINT considerations were frequently identified/addressed too late or not considered. In many cases, the tests were designed exclusively to accommodate RAM or hardware testing.

Second, manual human performance measurement requires tremendous personnel resources. As illustrated during the AN/TRC-170 FOTE, these resources were limited and impacted the quality of the data collected. The obvious solution is to use automated data collection methods, but this remains difficult for U.S. Army operational test and evaluation due to the variety of systems tested, the environment in which they are tested, and the costs of test equipment and instrumentation.

Third, in order for MANPRINT data to be of high quality, MANPRINT personnel need to be involved with the test planning from the very beginning. As was illustrated by the MSE C2E plan development subtask, all too often test events can eclipse the planning. MANPRINT personnel need to define their test requirements in terms of issues and criteria, experimental design, instrumentation, and resources very early in the test cycle in order for them to be adequately integrated into the other test requirements. Prospects for success can be increased by taking an aggressive lead in test planning, but receptive test agency personnel are also essential.

The final issue involves methodology. With the advent of the MANPRINT initiative, a number of test requirements became highly visible in operational testing. These included manpower, personnel, training, and human performance. It became apparent during the development of the MANPRINT portion of the MSE IEP that current methods were not adequate for collecting quality data on these requirements. This was further reinforced by the experiences on the AN/TRC-170 and SINCGARS V tests. To adequately answer the test issues associated with the domains of MANPRINT, new techniques and methods for data collection, reduction,

analysis, and evaluation need to be developed. The ideal solution would be a set of procedures for MANPRINT operational test and evaluation that provide guidance on how to perform data collection and analysis adaptable to a wide variety of system configurations and applications. These procedures would vastly improve the quality, reliability, validity, and comparability of MANPRINT data from operational test and evaluation.

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